

**Selected Aspects of the Ecology of the
Arizona Ridge-nosed Rattlesnake (*Crotalus willardi willardi*)
and the Banded Rock Rattlesnake (*Crotalus lepidus klauberi*)
in Arizona**

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FINAL REPORT

on the funded project

Ecology of the Arizona ridge-nosed rattlesnake
(*Crotalus willardi willardi*) in Arizona

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EXECUTIVE SUMMARY

Twenty-nine Arizona ridge-nosed rattlesnakes (*Crotalus willardi willardi*) were implanted with PIT-tags, 12 in the Huachuca Mountains and 17 in the Patagonia Mountains in southeastern Arizona. Thirty-nine banded rock rattlesnakes (*C. lepidus klauberi*) were implanted with PIT-tags in the Huachuca Mountains. We encountered the 68 snakes a total of 107 times and made 40 additional observations of unmarked *C. lepidus*. We recaptured eight (28%) of the 29 PIT-tagged *C. willardi* at least once and had an overall recapture rate (10 total recaptures of 29 marked snakes) of 34%. We recaptured 13 of the 39 tagged *C. lepidus* (33%), with an overall recapture rate of 62% (24 total recaptures of the 39 marked snakes).

The difference in the intercept terms of the regressions of mass on snout-vent-length between the two species is significant ($F=5.79$, $P=0.0191$); *C. lepidus* is proportionately lighter at all lengths than *C. willardi*.

Subcaudal scale counts were significantly higher for males than for females in both species ($P<0.05$). Male *C. lepidus* had significantly longer tails and more tail bands than females.

In the Huachuca Mountains, the most frequently occurring perennial plants within 2.5 m of *C. willardi* were bullgrass (*Muhlenbergia emersleyi*), Mexican pinyon (*Pinus cembroides*), Emory oak (*Quercus emoryi*), and Arizona white oak (*Q. arizonica*); the dominant plants were Arizona white oak, Mexican pinyon, and Emory oak. In the Patagonia Mountains, the most frequently occurring perennials within 2.5 m of *C. willardi* were silver leaf oak (*Q. hypoleucoides*), Mexican pinyon, squaw bush (*Rhus trilobata*), and bullgrass; dominants were silver leaf oak, squaw bush, Mexican pinyon, Arizona white oak, and Emory oak.

The mean body temperature of *C. willardi* found on the surface (24.2 ± 0.76 °C) did not differ significantly from that of *C. lepidus* (25.2 ± 0.83 °C). Body temperatures of both species were highly significantly correlated with surface temperatures and air temperatures at 5 mm and 1.5 m.

The two species exhibited marked differences in behavior. *C. lepidus* rattled much more readily than *C. willardi*, with 43% of confirmed behaviors either flight while rattling or rattling from under cover compared to a 3% frequency of those behaviors observed in *C. willardi*. *C. willardi* was observed crawling 39% of the time compared to 14% for *C. lepidus*.

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INTRODUCTION

The Arizona ridge-nosed rattlesnake (*Crotalus willardi willardi*) is known from only five mountain ranges in southern Arizona (Johnson 1983, Lowe et. al. 1986, Thirkhill and Starrett 1992, J. Howland, Arizona Game and Fish Department, pers. communication). It occurs at elevations from 4800-9000 feet in the Huachuca, Patagonia, Santa Rita and Whetstone mountains (Lowe et. al. 1986, Thirkhill and Starrett 1992) and the Canelo Hills (J. Howland, Arizona Game and Fish Department, pers. communication). A record from the Empire Mountains (Fowlie 1965) has yet to be confirmed. It is the only one of five named subspecies confirmed in Arizona, although *C. w. obscurus* likely occurs in the Peloncillo Mountains along the eastern border of the state. It is also possible that some form of *C. willardi* occurs in the Chiricahua mountains to the southeast. Although well known from localities like Ramsey Canyon in the Huachuclas and Cave Creek Canyon in the Santa Ritas, *C. w. willardi* is a poorly understood and little studied rattlesnake (Barker 1992).

There is no open season on the Arizona ridge-nosed rattlesnake in Arizona (Arizona Game and Fish Commission 1996) and the subspecies is currently listed as Wildlife of Special Concern in Arizona (Arizona Game and Fish Department 1996). It was formerly a candidate species on the list of Threatened Native Wildlife in Arizona (Arizona Game and Fish Department 1988). Woodcutting, illegal collecting, road development, and mining are considered the major threats, yet the effects of any of the above have yet to be studied. More importantly, no studies have been undertaken to acquire the baseline demographic and ecological data needed from undisturbed populations to properly assess what effect the above mentioned threats have on the Arizona ridge-nosed rattlesnake. Poaching is common, but its effects on these local populations are unknown. This is due to the paucity of reproductive data and other demographic information currently available. Most reproduction data come from captive observations and breeding (Martin 1975a, 1975b; McCrystal and Tryon in prep; Quinn 1977; Tryon 1978, 1985). Acquiring thorough reproductive and demographic data will allow proper assessment of the effects of the above mentioned land uses and illegal taking of specimens.

Klauber (1972) and Barker (1992) both discuss the described geographic races of *C. willardi* and their hypothesized phylogeny. The effect of the historical geography of the Sierra Madre Occidental and the associated climatic changes related to numerous glaciation events since the mid-Miocene on the races of *C. willardi* is discussed by Barker (1992). The restriction of the pine-oak woodland occupied by *C. willardi* to higher elevations serves to explain the current isolated populations observed today in all races. Intergradation between subspecies is unlikely given the current isolation of these subspecies. It can be further extrapolated that gene flow between the five mountain ranges occupied by *C. w. willardi* is probably similarly restricted. A thorough survey of the few areas where this may be possible (i.e. between the Canelo Hills and the Patagonias) is needed. We believe gene flow to be unlikely, however, and therefore, these five isolated populations constituting the entire known range of *C. w. willardi* in Arizona each take on more significance towards the future

stability of the race in the state. Although each of the above Arizona populations are considered to be *C. w. willardi* (Barker 1992), their isolation from each other renders each population more vulnerable. Repopulation from a neighboring population would be extremely unlikely should there be any catastrophic event to one of them.

There is no open season on the banded rock rattlesnake, *Crotalus lepidus klauberi*, in Arizona (Arizona Game and Fish Department 1996). It is limited in its distribution in Arizona, occurring in sympatry with the Arizona ridge-nosed rattlesnake in the Huachuca, Santa Rita and Whetstone mountains and in the Canelo Hills. It also occurs allopatrically in the Chiricahua, Dos Cabezas, and Dragoon mountains (Lowe et al. 1986). *Crotalus lepidus* has not been recorded in the Patagonia Mountains. Little is known of the ecology of this snake in this western part of its range. *Crotalus lepidus*, as *C. willardi*, is commonly poached in Arizona. Baseline demographic and ecological data are needed to assess its population status and the effects of poaching and potential competitive interactions with *C. willardi*.

The primary objective of this study was to mark as many *C. willardi* as possible and up to 40 *C. lepidus* with PIT (passive integrated transponder) tags and attempt to collect baseline data on habitat description, demographics, and movements within the populations. We used two study sites, one in the Huachuca Mountains and the other in the Patagonia Mountains, to hopefully maximize the demographic and ecological data obtained. Long range goals for this project (McCrystal and McCrystal 1993) beyond the duration of this grant will be to gather specific data on size-class distributions, inbreeding, reproductive behaviors, growth rates, parturition dates, movement patterns, and environmental correlates with behavior and seasonal activity patterns. This will be done with the aid of radio telemetry and DNA fingerprinting. We hope to assess the effects of competition, if any, between the two species. This is why we chose the Patagonia site for comparison, as no *C. lepidus* are known from there. We also hope to assess the effects of research methods on these sensitive species.

METHODOLOGY

Study sites.--Two areas were studied: the Sunnyside drainage in the Huachuca Mountains, Cochise County, Arizona, and a canyon in the Patagonia Mountains, Santa Cruz County, Arizona (Fig. 1). These sites were chosen after an intensive four year evaluation of several possible areas in these mountain ranges, as well as the Santa Rita Mountains to the northwest. Both study areas represent typical pine-oak woodland canyon habitat known to be commonly occupied by *C. willardi* and *C. lepidus* (Lowe et al. 1986).

The study canyons were marked with numerically sequential wooden stakes at 50 m intervals. The stakes were placed in unobtrusive locations along the canyon walls and recorded. Large natural nearby landmarks were also noted to help locate hard-to-find stakes and to ascertain whether any vandalism or loss had occurred. These stakes served as permanent markers to which we would reference a snake's exact location when observed, using a compass and tape measure (e.g., *C. willardi* #9315 21 m 242° WSW stake #14).

Survey season.--No surveys were taken during breeding and parturition season to minimize impact upon normal breeding and movement behavior in our study populations. We have heard of other attempts to conduct this sort of study with montane rattlesnake species that resulted in few or no recaptures, but no reports have appeared in the literature. In our preliminary season of marking *C. w. willardi* (1991), we experienced nearly 40% recapture rate. We believe that our familiarity with our study sites, combined with the minimal disturbance (handling time < 15 minutes) of the snakes was responsible for this high initial recapture rate.

We also believe that staying out of the canyons during periods of high snake social activity has put less stress on these species. We based the decision on when to survey on our own and other's observations. Gloyd (1937) reports that a female *C. lepidus* taken in early July was gravid, and a newborn brood of *C. lepidus* was found on 21 July. Broods of *C. lepidus* are reported born in July and August (Johnson 1987). *Crotalus w. willardi* are reported to breed in July, with captive breedings observed in April-August (Lowe et al. 1986). Babies are born in July and August (McCrystal and Tryon in prep.). Kevin Bowler (pers. communication) found a female coiled with a newborn brood of babies in Sunnyside, Huachuca Mountains, in August. From these, and our observations over the past 20 years, we decided that the fall months from September through December were the best months for surveying the study areas to minimize effects on the snake populations. All age classes of both sexes of both species are active in the fall, yet it appears that most reproductive behavior (social) is over for the year. Though not during this study, we have observed pairs of both species copulating as late as early October, and we did not disturb them. Both species have been observed by HKM breeding in captivity into October. It appears, however, that the main focus for both species is feeding, probably gearing up for the cold months ahead.

Specimen location, marking and data acquisition.--Snakes were located by intensive search of the study areas. When possible, the canyons were searched by three people, with one hunting

the right side canyon wall, one hunting the creek center canyon bottom and the other hunting the left side canyon wall. When only two people were hunting, the canyon was traversed by both, or each took one side and the creek center. When a snake was located, it was secured with tongs and its head placed in an appropriately sized clear plastic tube so that it was safe to handle without risk of snakebite (Murphy 1971). Tubes are open-ended to afford easy respiration for the snakes. At no time were any snakes pinned behind the head.

Snakes were scanned for PIT-tags using a Taymar Model 100 portable reader. If the reader indicated no tag, the snake was marked by injecting a PIT-tag subcutaneously between scale rows two and three, approximately 15 scale rows anterior to the cloacal vent on the snake's left side. This area was first thoroughly scrubbed using a complexed-iodine solution such as Betadine Surgical Scrub. The PIT-tag was then inserted with a sterile ten gauge needle. The needle was not inserted past the length of the bevel. A sterile stainless steel plunger was then used to feed the tag forward out of the needle to just anterior to the distal-most tip of the needle bevel. The needle was then withdrawn, and the entire area rescrubbed with the complexed iodine solution and sealed with sterile veterinary adhesive. The above procedure was recommended by James L. Jarchow, D.V.M. PIT-tags were chosen because they have a relatively long life with low failure rate and apparently have no detrimental effect on growth rate and speed of snakes that have been implanted (Camper and Dixon 1988, Keck 1994).

Snakes were measured using a millimeter straight ruler [snout-vent-length (SVL), tail length (posterior edge of the anal scale to the anterior edge of the rattle), base rattle segment width (the dorsoventral width of the most proximal rattle segment, measured at its widest point), terminal rattle segment width (the dorsoventral width of the most distal rattle segment, measured at its widest point)]. Snakes were weighed in preweighed cloth sacks using Pesola spring scales (Forestry Suppliers, Inc., Jackson, Mississippi). Snakes were sexed by probing.

Dorsal body bands (including the nuchal band or blotch, counted dorsolaterally down the right side to the anal scale) and tail bands were recorded to help identify marked snakes and document variation in populations and through ontogeny (Klauber 1952, 1972). Obvious color pattern anomalies were recorded such as number of broken, incomplete or faded bands.

Subcaudal scales were counted along the right side of the ventral surface of the tail from the first subcaudal row posterior to the anal scale up to but not including the first rattle fringe scales. Split and/or paired subcaudals were recorded.

As part of another study, occasional venom samples were recovered for isoelectric focusing and Western blotting methods. Snakes were not "milked", rather a voluntary sample was taken by letting the snake bite the soft top of a collecting container. Venom samples were, and are being, used for intra- and inter-population venom component variation studies (La Duc et al. 1994, Rael et al. 1992).

For each snake encountered we also recorded elevation, aspect, slope, wind speed, cloud cover, time snake first observed, time snake released, present or recent precipitation, site description (including topography, substrate, vegetation, proximity to creek center, refuge or basking sites), environmental and snake core body temperatures, and other pertinent data such as stool contents, prey items nearby, scars, etc. Elevation was estimated to the nearest 100 ft using a calibrated altimeter. Aspect was measured with a compass. Slope was measured with a clinometer. Occasionally, if a snake was found on a very steep hillside on a flat spot or rock etc., both the slope of the collection locality and the hillside were recorded. Wind speed was estimated using the Beaufort scale, cloud cover by ocular estimate. Surface, air temperatures at 5 mm and 1.5 m, and core body temperatures were taken with a quick-reading cloacal thermometer (Miller-Weber, Queens, NY). Contact time (the entire time we spent manipulating or interfering with the snake, from time of initial observation to release) was calculated. Woody perennials and perennial grasses occurring within a 2.5 m radius of the initial capture sites for *C. willardi* were ranked according to structural dominance. Samples were taken to identify or verify plant species near the capture site. We recorded any observations of predation and palpated each snake for food items in the digestive tract. If a snake defecated during processing, we tried to identify food items in the feces.

Behavior.--We attempted to define what particular behaviors we observed when we first located snakes in the field. It is important to note that, by design, the seasonally restricted data collecting period that we chose eliminated the opportunity to observe many types of behavior, particularly social and reproductive. Additionally, because telemetry was not used in this study, we had to rely on more traditional search tactics. As a result, it was often the snakes that "found us", or helped us to find them, by rattling and or crawling away when we came too close, thereby alerting us to their presence. In these situations, the specific behavior that had been taking place prior to us disturbing them is unknown; we did not attempt to speculate on what that behavior might have been. When we did have the opportunity to observe "undisturbed" snakes, we categorized those behaviors (Table 1). To compile data sets on the complete behavioral repertoire for either *C. willardi* or *C. lepidus* will require year-long radio telemetry for several consecutive years.

Statistical analyses.--*Crotalus willardi* data from each mountain range were pooled for most analyses because of small sample sizes. Length-mass relationships were compared using analysis of covariance. We tested first for equal slopes of the regressions (interaction between categorical variables such as sex or species and the continuous independent variable length). If slopes were not significantly different, we tested for equal intercept (marginal test of significance of the categorical variable). The regression lines reported are the result of linear regression on \log_{10} -transformed data from initial captures. For morphological comparisons between sexes (tail length, number of subcaudals, and tail bands), we used a two-sample F test for variances, followed by the appropriate one or two-tailed, two-sample t-test adjusted for unequal variances when appropriate (Zar 1984). The log-likelihood-ratio (G) test with Williams' correction was used to test for random elevational distribution; recaptures

Table 1. Behavioral categories in *Crotalus lepidus* and *C. willardi*, Arizona 1991-1994.

<u>Behavior</u>	<u>Description when snake first observed</u>
Flight, rattling	Crawling away from us or toward cover, rattling.
Flight, not rattling	Crawling away from us or toward cover, not rattling.
Crawling	Moving, but not in flight or foraging.
Foraging	Moving in "foraging gait," a slow, methodical, jerking-forward crawl.
Coiled, rattling	Coiled, rattling.
Coiled, not rattling	Coiled, not rattling.
Stretched out	Stretched out, not moving.
Basking	Partially or fully exposed, coiled or otherwise, but snake had to have been undisturbed and postured to thermoregulate from either substrate or sun.
Hunting position	Ready-to-strike posture, with body looped, not coiled, and head held low, not high; often used by <i>C. lepidus</i> in the rocks.
Rattled from under cover	Snake discovered by hearing it rattle from under cover (rocks, leaves, logs, etc.).
Undetermined	Unable to assign any of the above specific behaviors to snake.

were not included in the analysis and sexes and ages were pooled. Elevation categories were pooled so that there were no expected frequencies < 3 (Sokal and Rohlf 1995). The Mann-Whitney U test was used to test for differences between the two mountain ranges in the slope of the terrain at first capture sites of *C. willardi*; sexes and ages were pooled.

Because of small sample sizes, ages, sexes, and recaptures were pooled in the temperature analyses. Only temperatures of snakes on the surface were included in the analysis. Sample sizes were too small to test for body temperature differences associated with individual behaviors. Differences between species in slopes of the terrain and body temperatures during surface activity were tested using the two-sample F test, followed by the appropriate two-tailed, two-sample t-test, adjusted for unequal variances when appropriate (Zar 1984).

Means are presented ± 1 standard error (SE), unless otherwise indicated. Critical values for hypothesis testing were at $\alpha = 0.05$ level of significance.

RESULTS

During 1991-1994, we PIT-tagged 29 *C. willardi* (12 in the Huachuca Mountains, 17 in the Patagonias). We made 43 separate observations (29 initial captures, 10 recaptures, 4 observations) of those 29 snakes; the four observations were of marked snakes (identified by reading the PIT tag without disturbing the snake) seen within 14 days of the initial capture. These four observations were not computed in our recapture percentages. We tagged 39 *C. lepidus* in the Huachuca Mountains, with 64 separate observations of those 39 snakes. We made 40 additional observations of *C. lepidus* that we were unable to catch or chose not to. *C. lepidus* were encountered more frequently than *C. willardi*, and, as we were attempting to assess the effects of our methods on the snakes, we sometimes elected not to catch all snakes observed. Each snake was at least checked to see if it was PIT-tagged. We recaptured eight of the 29 PIT-tagged *C. willardi* (28%) at least once and had an overall recapture rate of 34% (10 total recaptures of 29 marked snakes). We recaptured 13 of the 39 tagged *C. lepidus* (33%), with an overall recapture rate of 62% (24 total recaptures of the 39 marked snakes).

Body size.--*Crotalus willardi*. Size class and gender distributions for the Huachuca and Patagonia mountains populations are presented in Figs. 2 and 3. At both sites, only males exceeded 450 mm SVL. Sex ratio (males to females) did not differ significantly from 1 in either the Huachucas (7:4) or the Patagonias (5:7). Smaller snakes were more difficult to sex than larger ones, with all snakes of unknown gender smaller than 300 mm SVL. Twenty-nine percent (5/17) of the *C. willardi* found at the Patagonias were less than 250 mm SVL, compared to 8 percent in the Huachucas (1/12); these percentages were not significantly different ($P > 0.05$).

The length-mass relationship did not vary between the Huachuca and Patagonia mountains (slope: $F_{1,27}=0.84$, $P=0.3690$; intercept: $F_{1,27}=0.29$, $P=0.1022$). The length-mass relationship did not vary between sexes, either (slope: $F_{1,27}=0.16$, $P=0.6897$; intercept: $F_{1,27}=0.66$, $P=0.4285$). We therefore combined mountain ranges and sexes to calculate the length-mass relationship for the species:

$$\log_{10} \text{ mass} = -5.704 + 2.8 \log_{10} \text{ SVL} \quad (\text{Equation 1})$$

$$(P < 0.0001, F_{1,27}=194.11, R^2=0.878).$$

Crotalus lepidus. Size class and gender distributions for the Huachuca Mountains population are presented in Fig. 4. Only males exceeded 450 mm SVL. Sex ratio (males to females) did not differ from one (17:18).

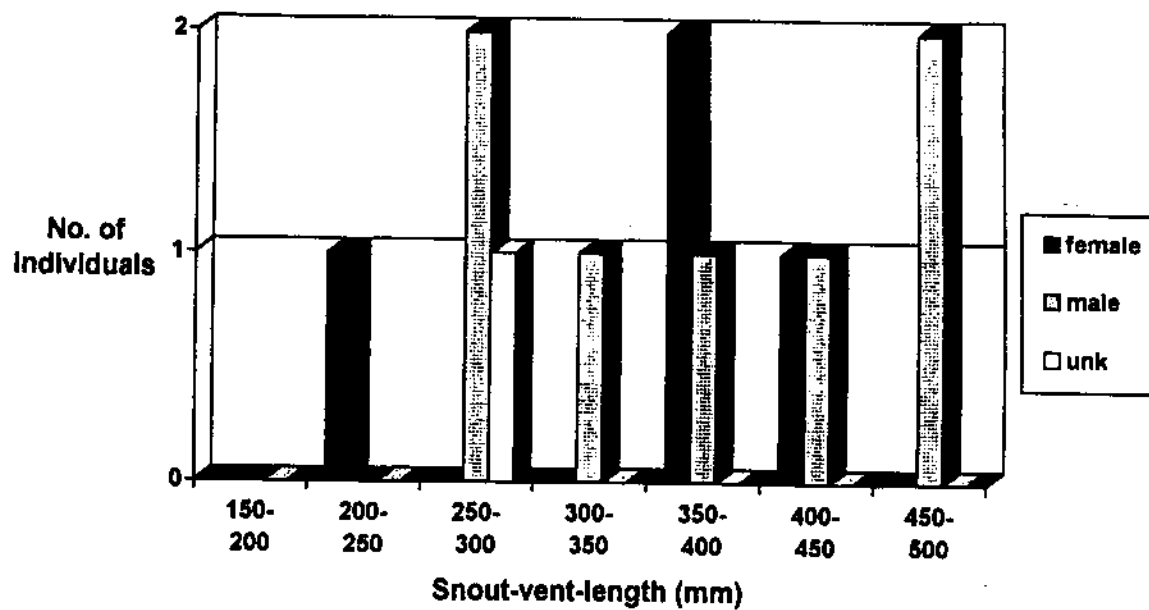


Figure 2. Size class distribution of *Crotalus willardi* in a population in the Huachuca Mountains, Cochise County, Arizona, 1991-1994.

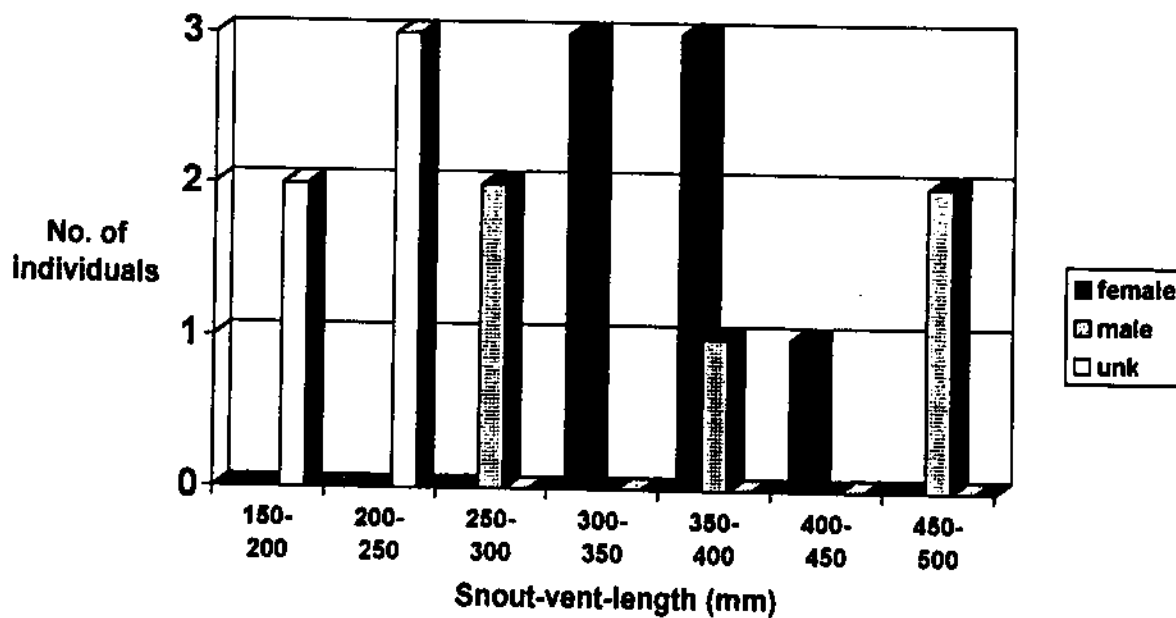


Figure 3. Size class distribution of *Crotalus willardi* in a population in the Patagonia Mountains, Santa Cruz County, Arizona, 1991-1994.

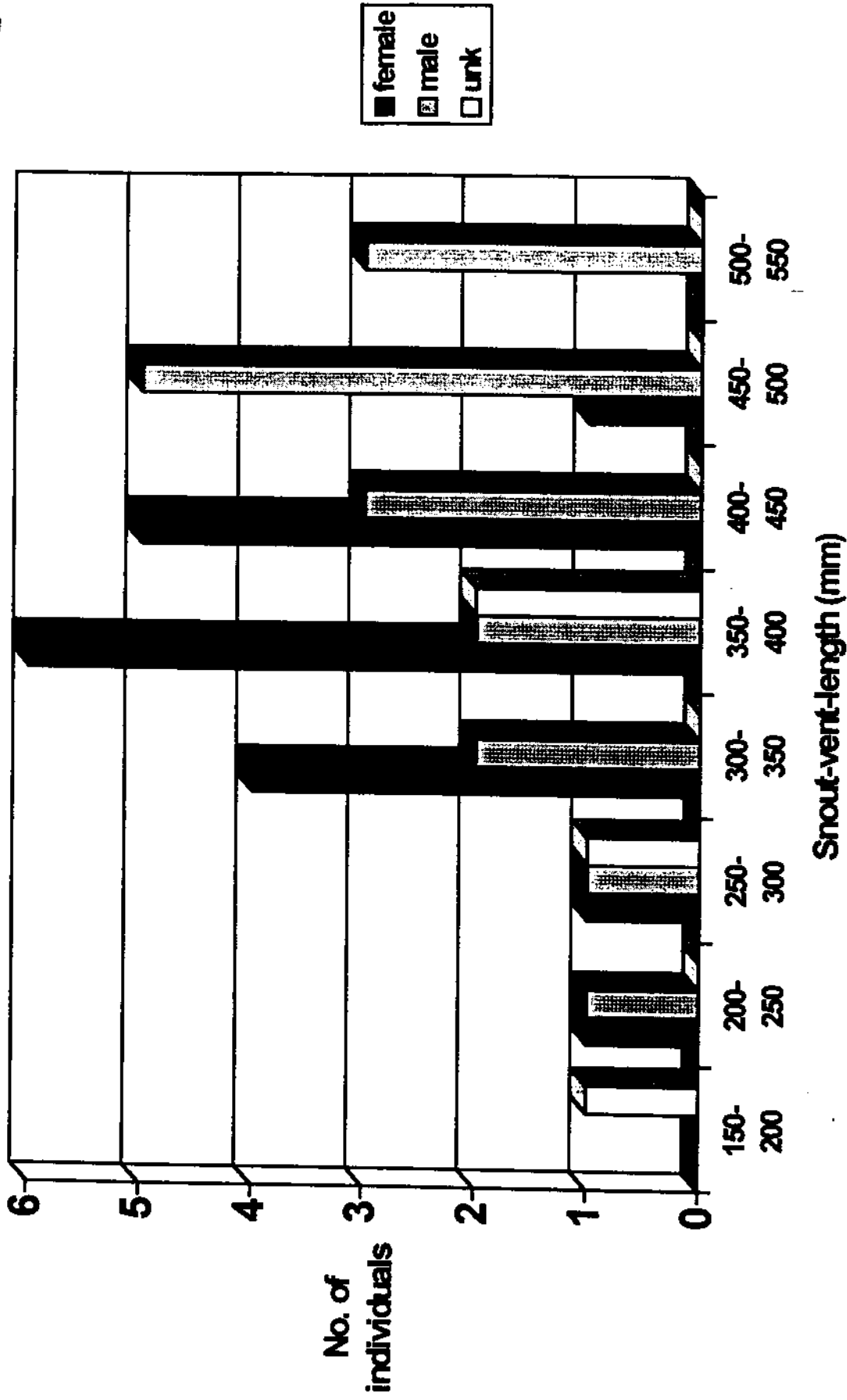


Figure 4. Size class distribution of *Crotalus lepidus* in a population in the Huachuca Mountains, Cochise County, Arizona, 1991-1994.

The length-mass relationships of the sexes did not differ significantly (slope: $F_{1,32}=1.73$, $P=0.1978$; intercept: $F_{1,32}=0.05$, $P=0.8293$). We therefore combined data for all snakes to calculate the length-mass relationship for the species:

$$\log_{10} \text{ mass} = -5.586 + 2.8 \log_{10} \text{ SVL} \quad (\text{Equation 2})$$

$$(P < 0.0001, F_{1,25}=265.21, R^2=0.883).$$

Comparison of species. Slopes of the length-mass relationships did not differ significantly between the species ($F_{1,64}=0.08$, $P=0.7780$). However, intercepts did differ significantly ($F_{1,64}=5.79$, $P=0.0191$). Both species add the same proportion of weight for a given proportional increase in body length (equal slopes). However, at any given length, *C. willardi* is approximately 20% heavier than *C. lepidus* (Table 2). Because the reported regression lines are not precisely parallel, the ratio of predicted weights from the reported lines varies somewhat from 20%.

Band patterns, tail lengths, and subcaudal scales.--Subcaudal scale counts were significantly higher for males than for females in both species ($P < 0.05$, Table 3). Male *C. lepidus* had significantly longer tails and more tail bands than females; numbers of tail bands and tail lengths were not significantly different between sexes in *C. willardi* (Table 3).

Growth.--Growth data are presented for 4 *C. willardi* and 8 *C. lepidus* in Tables 4 and 5, respectively. Sample sizes are too small to draw broad conclusions. All 5 of the mass changes measured in the 4 *C. willardi* were positive; 5 of the 16 mass changes measured in the 8 *C. lepidus* were losses.

Elevation.--The elevational distribution of *C. willardi* did not differ from random in either the Huachuca or Patagonia mountains (Huachuca Mountains: $G'=1.3390$, $P > 0.50$, $df=2$; Patagonia Mountains: $G'=1.8283$, $P > 0.25$, $df=3$). The distribution of *C. lepidus* with respect to elevation was highly significantly different from random in the Huachuca Mountains ($G'=16.9851$, $P < 0.001$, $df=3$); the correlation of number of *C. lepidus* seen and elevation was not significant ($P > 0.05$).

Vegetation.--Frequencies of occurrence of woody perennials and perennial grasses and rank sums of those plant species within a 2.5-m radius of the initial capture sites of *C. willardi* are presented in Table 6. In the Huachuca Mountains, the most frequently occurring perennial plants within 2.5 m of *C. willardi* were bullgrass (*Muhlenbergia emersleyi*), Mexican pinyon (*Pinus cembroides*), Emory oak (*Quercus emoryi*), and Arizona white oak (*Q. arizonica*); the dominant plants were Arizona white oak, Mexican pinyon, and Emory oak.

In the Patagonia Mountains, the most frequently occurring perennials within 2.5 m of *C. willardi* were silver leaf oak (*Q. hypoleucoides*), Mexican pinyon, squaw bush (*Rhus*

Table 2. Predicted masses and ratios of masses for *C. willardi* and *C. lepidus*, using a parallel slope model to simplify patterns. Predicted masses and ratios from reported regression lines (Equations 1, 2) are shown in parentheses. Snout-vent-lengths (SVLs) used to demonstrate predictions of model and Equations 1 and 2 are in size range of observed snakes.

<u>SVL (mm)</u>	<u>Predicted mass (g)</u>		<u>Ratio of predicted masses (CW:CL)</u>
	<u><i>C. lepidus</i> (CL)</u>	<u><i>C. willardi</i> (CW)</u>	
200	7.211 (7.350)	8.630 (8.380)	1.20:1 (1.14:1)
400	51.863 (51.307)	62.067 (61.650)	1.20:1* (1.20:1)

<u>SVL ratio</u>	<u>Ratio of predicted masses (CW:CL)</u>	
400:200	7.2:1 (6.98:1)	7.2:1 (7.36:1)**

**C. willardi* is consistently about 20% heavier than *C. lepidus* of the same length.

**In this example, *C. lepidus* and *C. willardi* show the same proportional mass gain (720%) for a given proportional gain in length (100%).

Table 3. Length, mass, band patterns, and subcaudal scales in *Crotalus willardi* and *C. lepidus* in the Huachuca and Patagonia mountains, Arizona, 1991-1994. SVL = snout-vent-length; Tail L = tail length. Mean \pm SE (range, N).

Sex	Mass (g)	SVL (mm)	Tail L (mm)	Body Bands	Tail Bands	Subcaudals
<i>C. willardi</i>						
F	43.3 \pm 6.10 (16-88, 11)	348.3 \pm 15.73 (234-412, 11)	33.3 \pm 0.94 (30-39, 11)	22.1 \pm 0.58 (18-24, 10)	2.4 \pm 0.27 (2-4, 10)	24.4 \pm 0.47 (22-27, 11)
M	63.8 \pm 11.36 (16-140, 12)	375.2 \pm 25.98 (254-492, 12)	40.2 \pm 2.80 (28-54, 12)	21.0 \pm 0.48 (18-23, 12)	3.1 \pm 0.19 (2-4, 12)	27.7 \pm 0.53 (24-30, 12)
<i>C. lepidus</i>						
F	44.5 \pm 4.33 (18-74, 17)	366.6 \pm 12.98 (238-450, 18)	29.8 \pm 1.56 (19-45, 18)	18.5 \pm 0.41 (15-21, 18)	2.2 \pm 0.12 (1-3, 18)	20.2 \pm 0.29 (18-22, 18)
M	65.6 \pm 9.06 (16-130, 17)	416.9 \pm 21.16 (248-540, 17)	42.7 \pm 2.65 (23-60, 17)	17.9 \pm 0.30 (15-20, 17)	3.0 \pm 0.08 (2-4, 17)	25.9 \pm 0.18 (25-27, 17)

Table 4. Growth in and distance moved by *Crotalus willardi* in the Huachuca (H) and Patagonia (P) mountains, Arizona, 1991-1994. SVL = snout-vent-length; Tail L = tail length.

Site	Snake No.	Sex	SVL (mm)	Δ SVL (mm)	Tail L (mm)	Δ Tail L (mm)	Tail L (mm)	Mass (g)	Δ Mass (g)	Distance moved (m)	Date dd/mm/yy	No. days
H	7F7E6E5E0C	M	340	-	41	-	-	58*	-	-	14/09/91	-
			340	0	41	0	0	78	20	9	28/09/91	14
H	7F7D056F64	M	282	-	30	-	-	62	-	-	28/09/91	-
			433	151	46	16	16	68	6	11	29/09/94	1097
H	7F7E6E5D63	M	354	-	31	-	-	42	-	-	06/09/92	-
			-	-	-	-	-	-	-	91	20/09/92	14
			394	40	34	3	3	67	25	84	02/11/93	408
			401	7	34	0	0	84*	17	105	29/09/94	331
H	7F7E562A0D	M	439	-	51	-	-	69	-	-	15/10/93	-
			-	-	-	-	-	-	-	8	02/11/93	18
P	7F7D072D74	F	310	-	30	-	-	25	-	-	18/10/91	-
			380	70	40	10	10	60	35	0	15/10/92	363
P	7F7D153C04	F	350	-	35	-	-	50	-	-	18/10/91	-
			-	-	-	-	-	-	-	46	24/10/91	6

* food bolus present.

1 snake had moved 12 m within 7.5 hours after initial capture; snake was found back at initial capture location 363 days later.

Table 5. Growth in and distance moved by *Crotalus lepidus* in the Huachuca Mountains, Cochise County, Arizona, 1991-1994. SVL = snout-vent-length; Tail L = tail length.

Snake No.	Sex	SVL (mm)	Δ SVL (mm)	Tail L (mm)	Δ Tail L (mm)	Mass (g)	Δ Mass (g)	Distance moved (m)	Date dd/mm/yy	No. days
7F7D1E7B6F	M	510	-	50	-	110	-	-	14/09/91	-
		510	0	50	0	130	20	-	29/09/91	15
		557	47	51	1	130	-	-	06/11/92	404
7F7D154223	M	440	-	40	-	80	-	-	14/09/91	-
		452	12	43	3	105	25	-	06/09/92	358
7F7D084701	M	490	-	48	-	95	-	-	28/09/91	-
		516	26	48	0	80	-15	-	04/10/92	372
		520	4	48	0	95	15	46	03/11/93	395
		520	0	50	2	84	-11	59	23/10/94	354
7F7E6E4861	M	416	-	40	-	52	-	-	06/10/91	-
		464	48	64	24	58	6	9	03/10/92	363
7F7E6E4752	M	248	-	23	-	20	-	-	28/10/91	-
		313	65	28	5	23	3	11	03/10/92	341
		-	-	-	-	-	-	11	04/10/92	1
7F7D1A4860	M	372	-	38	-	35	-	-	07/10/92	-
		375	3	39	1	29	-6	29	16/10/93	374
7F7E6E4E36	M	480	-	50	-	59	-	-	20/09/92	-
		486	6	49	-1	75	16	-	11/09/94	721

Table 5. Continued.

Snake No.	Sex	SVL (mm)	Δ SVL (mm)	Tail L (mm)	Δ Tail L (mm)	Mass (g)	Δ Mass (g)	Distance moved (m)	Date dd/mm/yy	No. days
7F7D042E5A	F	388	-	31	-	58	-	-	28/09/91	-
		415	27	33	2	50	-8	0	06/11/92	405
		415	0	33	0	50	0	0	11/03/93	125
		415	0	35	2	66	16	0	02/11/93	236
7F7D152E37	F	351	-	26	-	32	-	-	06/10/91	-
		-	-	-	-	37	5	5	28/10/91	22
		390	39	30	4	44	7	17	04/10/92	340
7F7E6E5B16	F	238	-	19	-	20	-	-	28/10/91	-
		344	106	26	7	23	3	69	16/10/93	719
7F7E6E4A20	F	410 ¹	-	40 ¹	-	58	-	-	20/09/92	-
		430	20	33	-	45	-13	0	04/10/92	14
		436	6	33	0	48	3	15	01/09/93	332

¹Assumed these measurements in error.

Table 6. Frequencies of occurrence and rank sums of dominants of perennial plants within 2.5 m of initial capture sites of *Crotalus willardi* in the Patagonia and Huachuca mountains, Arizona, 1991-1994. ARXX=*Aristida* sp., BOGL=*Bouvardia glaberrima*, BRS1=*Brickellia* sp. 1, BRS2=*Brickellia* sp. 2, CARX=*Carex* sp., DAWH=*Dasylirion wheeleri*, ERSP=*Eragrostis* sp., GAWR=*Garrya wrightii*, JUDE=*Juniperus deppeana*, MUEM=*Muhlenbergia emersleyi*, PICE=*Pinus cembroides*, PIEN=*P. engelmannii*, QUAR=*Quercus arizonica*, QUEM=*Q. emoryi*, QUHY=*Q. hypoleucoides*, RHTR=*Rhus trilobata*, UNK*=unknowns. UNKG=unknown grass. Freq.=frequency, Rel. Freq.=relative frequency.

Patagonia Mountains				Huachuca Mountains			
Species	Freq.	Rel. Freq.	Rank Sum	Species	Freq.	Rel. Freq.	Rank Sum
QUHY	12	0.67	22	MUEM	6	0.75	11
PICE	8	0.58	14	PICE	6	0.75	22
RHTR	7	0.58	18	QUEM	6	0.75	21
MUEM	6	0.50	14	QUAR	5	0.63	23
QUAR	5	0.42	10	ERSP	3	0.38	2
QUEM	4	0.33	14	JUDE	3	0.38	11
JUDE	3	0.25	10	UNK3	3	0.38	3
GAWR	2	0.17	2	UNK5	3	0.38	1
PIEN	2	0.17	4	UNK6	3	0.38	1
ARXX	1	0.08	3	BRS1	2	0.25	1
DAWH	1	0.08	4	BRS2	1	0.13	2
BOGL	1	0.08	2	CARX	1	0.13	1
UNKG	1	0.08	1	QUHY	1	0.13	3
				RHTR	1	0.13	1
				UNK4	1	0.13	4

trilobata), and bullgrass; dominants were silver leaf oak, squaw bush, Mexican pinyon, Arizona white oak, and Emory oak.

Temperatures.--Body temperatures of *C. lepidus* and *C. willardi* correlated significantly with air temperatures at 5 mm and 1.5 m and surface temperatures (Table 7). Mean body temperatures of *C. lepidus* and *C. willardi* on the surface did not differ significantly (Variance F test: $F=1.0239$, $P=0.4722$; t-test with equal variances: $t=0.9271$, $P=0.3581$, $df=52$).

Movements.--Eight total movements by 6 *C. willardi* were measured, ranging from 0-105 m over 6 to 1097 days (Table 4). Fourteen total movements by 8 *C. lepidus* ranged from 0-69 m over 1-719 days (Table 5).

Behavior and diet.--In 23% of the observations of *C. willardi* (10/43), we could not confirm one of the 10 specific behaviors we had defined; we could not confirm the behaviors of 35% of *C. lepidus* (36/104) (see Methods, Tables 1, 8).

While our behavior data are preliminary, some interesting trends are nevertheless evident. When only confirmed behaviors are compared between the two species (Table 8), some apparent differences between the two species emerge. *C. lepidus* was observed to take flight while rattling much more frequently than *C. willardi* (23% vs 3%), whereas *C. willardi* took flight without rattling more often than *C. lepidus* (12% vs 2%). *C. willardi* was observed crawling more than *C. lepidus* (39% vs 14%). These crawls were not the fast, direct crawls of snakes in flight, but were deliberate slow-paced crawls without the head-jerking gait of actively foraging animals. *C. willardi* was observed basking more than *lepidus* (24% vs 12%). *C. lepidus* was observed in the hunting position more often (11% vs 3%). This is likely collecting bias, as we have often seen *C. willardi* using the same position tactics before and after the data were collected for this project. *C. willardi* appear to sit by bunchgrass, logs, or rocks, whereas *C. lepidus* appear to prefer rocks. *C. lepidus* was much more likely to buzz intruders whether it was on the surface or in the rocks. *C. lepidus* was observed rattling from under cover more frequently than *C. willardi* (20% vs 0%).

During our study *C. willardi* ate both lizard and mammal prey (Table 9). Only lizard prey were confirmed for *C. lepidus* (Table 9). During this study spiny lizards (*Sceloporus jarrovi*) were offered to and eaten by *C. lepidus* on two occasions in 1994 by HKM.

In the Huachuca Mountains, on five occasions during the study we observed pairs of *C. lepidus* together and once we saw a pair of *C. willardi* (Table 10). We did not observe pairs of *C. willardi* together in the Patagonia Mountains during 1991-1994.

Marking problems.--Among the 29 *C. willardi* and 39 *C. lepidus* tagged, we observed 3 problems with our marking and handling methods. We had problems using the syringe plunger system for tagging; we believe it is too crude and think our method allows us much

Table 7. Body temperatures and associated environmental temperatures (degrees C) of *Crotalus lepidus* and *C. willardi* on the surface in the Huachuca and Patagonia mountains, Arizona, 1991-1994. Tb=body temperature; Ts=surface temperature; Ta@5mm=air temperature at 5 mm above surface; Ta@1.5m=air temperature at 1.5 m.

		<u>R-square</u>	<u>P</u>	<u>n</u>
<i>C. lepidus</i>				
Ts	vs Tb	0.72	<0.0001*	15
Ta@5mm	vs Tb	0.54	0.0018*	15
Ta@1.5m	vs Tb	0.52	<0.0001*	25

C. willardi

Ts	vs Tb	0.56	0.0013*	15
Ta@5mm	vs Tb	0.67	0.0002*	15
Ta@1.5m	vs Tb	0.66	<0.0001*	28

	<u>Mean</u>	<u>SE</u>	<u>n</u>
<i>C. lepidus</i>			
Tb	25.2	0.83	25
Ts	22.0	0.95	15
Ta@5mm	23.9	1.24	15
Ta@1.5m	23.8	0.80	25

C. willardi

Tb	24.2	0.76	29
Ts	22.9	1.03	15
Ta@5mm	23.2	1.02	15
Ta@1.5m	21.5	0.67	28

*Correlations highly significant ($P < 0.01$).

Table 8. Behavior observed in *Crotalus willardi* in the Huachuca and Patagonia mountains and *Crotalus lepidus* in the Huachuca Mountains, Arizona, 1991-1994.

Behavior	Observations			
	<i>C. willardi</i>		<i>C. lepidus</i>	
	No.	%	No.	%
Flight, rattling	1	3	15	23
Flight, not rattling	4	12	1	2
Crawling	13	39	9	14
Foraging	1	3	0	0
Coiled, rattling	0	0	1	2
Coiled, not rattling	3	9	6	9
Stretched out	2	6	4	6
Basking	8	24	8	12
Hunting position	1	3	7	11
Rattled from under cover	<u>0</u>	<u>0</u>	<u>13</u>	<u>20</u>
Totals for confirmed behaviors ¹	33	99	64	99

¹Behaviors that were not positively confirmed were excluded (10 for *C. willardi*, 36 for *C. lepidus*). Percentages do not sum to 100% because of rounding error.

Table 9. Observations on diet in *Crotalus willardi* and *C. lepidus* in the Huachuca (H) and Patagonia (P) mountains, Arizona, 1991-1994.

<u>Date</u> <u>dd/mm/yy</u>	<u>Site</u>	<u>Snake No.</u>	<u>Sex</u>	<u>Notes</u>
<i>C. willardi</i>				
14/Sep/91	H	7F7E6E5E0C	M	fur in stool
28/Sep/91	H	7F7D056F64	M	medium <i>Sceloporus</i> (ca. 70 mm SVL)
15/Oct/92	P	7F7D072D74	F	fur in stool
15/Oct/92	P	7F7E1C4C0D	F	medium food lump palpated
18/Oct/91	P	7F7D153C04	F	had eaten large mouse
24/Oct/92	P	7F7D153C04	F	still has food in it (same snake as 10/18)
29/Sep/94	H	7F7E6E5D63	M	recently fed, unknown prey
<i>C. lepidus</i>				
29/Sep/91	H	7F7D1E7557	M	passed large <i>Sceloporus</i> scale-laden stool
28/Oct/91	H	7F7E6E4752	M	lizard scales in stool
20/Sep/92	H	7F7E6E4F6A	F	has large food lump

Table 10. Pairs of *Crotalus lepidus* and *C. willardi* found together, Huachuca Mountains, Cochise County, Arizona, 1991-1994.

<u>Date</u> <u>dd/mm/yy</u>	<u>Female</u>	<u>Male #</u>	<u>Notes</u>
<i>C. lepidus</i>			
14/Sep/91	7F7D143861	7F7D117B6F	F with bright green stripe
20/Sep/92	7F7E6E4F6A	7F7E6E5040	2.4 m apart, F under rock with many shed skins
20/Sep/92	7F7E6E5C27	7F7E6E4E7E	in shrubs, south-facing hill, quietly coiled together
11/Mar/93	7F7D042E5A	7F7D084701	one layer down in rocks
30/Jul/94	Untagged	Untagged	basking in shrubs
<i>C. willardi</i>			
02/Nov/93	7F7D071714	7F7E562A0D	2 m from each other

more control of tag insertion. In two of the three problem snakes, we used the injection system of tags preloaded into the hypodermic needle by the manufacturer. These tags are designed for the spring-loaded syringe to inject them; we abandoned the use of these preloaded hypodermic needles and now only use sterile needles with hand-loaded and injected tags and plungers. One *C. willardi* (7F7E6E5D63) showed a small, soft abscess swelling around the PIT tag site two weeks after being tagged in September, 1992. This swelling was still evident in 1993 and 1994. The individual presented no other obvious negative effects; it displayed steady increases in length and mass at all recaptures.

Twice we had *C. lepidus* go into respiratory distress from being in tubes that were perhaps a little too tight to allow for unrestricted thoracic expansion. Both snakes were withdrawn from the tube and recovered within minutes. One (7F7D1A4860) was recaptured a year later and showed an 18% loss in mass. The snake did not appear underweight or unhealthy. This individual was stuck twice to get the PIT tag in due to problems with the preloaded tag in the hypodermic needle.

DISCUSSION

Length and mass relationships.--Our data suggest that both *C. lepidus* and *C. willardi* males attain longer lengths and greater masses than do females. This is the usual pattern in crotalids (Gloyd 1940, Klauber 1972, Lowe et al. 1986).

Even though *C. lepidus* add significantly less weight than do *C. willardi* as they add length, explanations for this difference are not obvious. Our behavioral data, which are too preliminary to be compelling, indicate that, contrary to the impressions of many, *C. willardi* may be the more active of the two species, with 42% of its confirmed behaviors being crawling or foraging compared to 14% for *C. lepidus* (Table 8). The difference in body form (mass to length) may be related to the tendency of *C. lepidus* to live in rocks, crevices, and burrows. While *C. lepidus* may not live in crevices exclusively, we regularly observe them hunting in them. The proportionately more slender build of adult *lepidus* may be more related to hunting and living among rocks, rock crevices, and burrows, than overall vagility. More detailed and intensive study is needed to reconcile these data.

Band patterns, tail lengths and subcaudal scales.--Even though the mean number of subcaudals of male and female *C. willardi* and the mean number of tail bands of male and female *C. lepidus* differed significantly, the ranges of each respective character overlapped, so that those characters can only be considered probable indicators of sex, not definitive characters. Barker (1992) also showed subcaudal scale count variation in *C. willardi* to be significantly different between sexes with similar patterns of variation [males: $\bar{x}=27.2$ (24-32); females: $\bar{x}=23.6$ (21-28), $P<0.0001$].

There was no overlap in numbers of subcaudal scales for male and female *C. lepidus* in the Huachuca Mountains. For our study population, it appears that subcaudal scale number may be used to differentiate between male and female *C. lepidus*. However, the ranges of subcaudal counts for males and females overlap for the subspecies *C. l. klauberi* (M 21-29, F 16-24, Gloyd 1940), so this character must be used with caution as an indicator of gender.

Elevation.--The lack of significant correlation between number of *C. lepidus* seen and elevation indicates that some other factor(s) than elevation alone is(are) responsible for the distribution of *C. lepidus* with respect to elevation being significantly different from random.

Vegetation.--Results presented are preliminary. We are re-evaluating the data collected up to now. When we address the data from 1995 and 1996, we will re-analyze habitat variables using multivariate techniques to quantify the respective contribution of several habitat components. At that time we will conduct a similar analysis of the same habitat components for *C. lepidus*. We will send a copy to Arizona Game and Fish Department when we report that information.

Weather.--Other than temperatures at time of snake observation, we did not collect consistent weather information. Estimates of wind speeds at time of capture were not made by all field personnel and variation between estimates by others make us hesitant to include those data in this report. We plan to work out our differences in wind speed estimates and gather consistent data in the future. We also plan to use temperature and humidity data loggers in the future to measure those variables at both study sites. We did not measure actual rainfall at either site because we could not figure out how to conceal a rain gauge and get reliable precipitation data. We believe rainfall information is important and needs to be collected.

Behavior and diet.--It is logical to assume that some of the observed behaviors are clearly related to our presence, i.e., flight, rattling or not, coiled rattling, and rattling from under cover. It is possible that some other person or predator induced these behaviors, but primarily these are reactions to our presence.

The foraging behavior observed in *C. willardi* is similar to behaviors observed in other crotalids such as *C. atrox*, *C. molossus*, and *C. scutulatus*. As the snake slowly crawls along, the head is thrust forward and then pulled back in a jerking fashion. As the head reaches its forward-most point, the tongue is extended. As the head is pulled back, the tongue is retracted. Interestingly, this behavior has not been observed in *C. lepidus*.

Both species have been observed in a sit-and-wait feeding strategy we have labeled the "hunting position" (Tables 1, 8). This posture allows the snake unrestricted ability to strike from a hidden position behind whatever object the snake is lying on. It has been most often observed in *C. lepidus* sitting on a rock or in a rock crevice, but has been observed in both species in or next to grass clumps or on logs.

The snake usually sits on the shaded face of a rock that has an approximate 90 degree angle at the top edge. The snake's head faces up toward the top edge of the rock, where the other face (or faces) of the rock meet. The tip of the snout is usually 2-8 cm below the top edge of the rock. The snake's body is arranged in side-to-side loops, each one wider than the next so the snake appears to form a triangle, with its head at the apex, when viewed from above. The lowest body loop or loops usually rest against another edge or turn in the rock. This may allow for leverage to push off against when the snake strikes its prey. This posture is obviously different from basking postures we have observed, and the snake rarely assumes it in or near usual basking sites. The snake appears ready to strike at anything that comes over the top edge of the rock. Snakes in this posture seem less likely to rattle or flee, and we have offered *Sceloporus jarrovi* to *C. lepidus* by sliding the lizard up over the edge of the rock. Each time the snake struck immediately at the lizard, and in a few instances even held onto and ate it in our presence. We intend to quantify these responses in the future.

We have only observed *C. w. willardi* using this hunting position in rocks one time (HKM). One of us (DFR) has also seen it once in *C. w. obscurus*. We have seen *C. w. willardi* use this position lying in or close to grass clumps, where they sometimes sit and

wait for prey. They do not always lie in such triangular loop patterns as *C. lepidus*, but it appears to us that they are engaging in similar behavior. We have not yet offered lizards or rodents to *C. w. willardi*. HKM has observed both species using the hunting position in captivity numerous times. CRS has seen a speckled rattlesnake (*C. mitchellii*) assume this hunting position twice in captivity, striking a live mouse immediately both times when it was dropped in front of the snake.

Our data on diet during this study are incidental and inconclusive. *C. willardi* mainly eat lizards and mice, but also take birds, snakes, and invertebrates, including centipedes and scorpions (Degenhardt et al. 1996, Lowe et al. 1986). Principal prey species for *C. lepidus* are lizards and small rodents, with frogs and small snakes occasionally taken (Degenhardt et al. 1996, Lowe et al. 1986). Neonate *C. lepidus* have eaten crickets in captivity (H. McCrystal unpublished data).

Marking and handling methods.—We believe our methods have proven successful with regard to minimizing stress of snakes. We have had numerous recaptures of both species and many times have seen the same individual in the same locality, indicating our disturbances have not made them move to another home. However, many individuals have not been seen after the initial encounter. We realize that they may have died naturally, or they may have been eaten, or simply missed by chance. We cannot, however, rule out that some individuals may have been stressed by our manipulations and may have moved elsewhere.

Reproduction.—Tryon (1978) suggested *C. w. willardi* has a biennial reproductive cycle and Johnson (1983) stated this to be a reasonable hypothesis. We believe that the only advantage to such a reproductive strategy is that it would allow time for the necessary energy acquisition to reinitiate reproduction when resources are scarce. It may be that, in the wild, it takes multiple years for females to acquire sufficient energy stores to produce young. However, in captivity, we have had *C. w. willardi* produce healthy large broods in successive years [HKM *C. w. willardi* female #8408 produced 5, 6, 7, and 10 live babies four years running, 1991-1994; female #KZG-CR-332 at the Knoxville Zoo produced broods of 5, 5, and 1 in 1991-1993 (B. Tryon pers. communication)]. While we cannot conclude that because snakes do something in captivity they also do it in the wild, our captive observations show that female *C. w. willardi* will reproduce annually if sufficient nutritional resources are available. Individuals are likely to go for two or more years without reproducing only if they are unable to acquire the necessary food base to produce young.

CONCLUSIONS

Crotalus w. willardi.--*C. w. willardi* are grassland and oak woodland-dwelling, middle-elevation, semifossorial snakes that are generalized in the cover they choose when opportunities are varied. We believe they prefer burrows or holes in the ground first and foremost, but they have been observed to use holes under rocks, holes in rock piles (which may lead to holes in the ground) and occasionally bunch grass clumps. They rarely seek refuge under dead logs. At elevations lower than our study area, where rock cover is less prevalent or non-existent, they seem to use burrows and bunch grass more frequently. We have observed *C. willardi* lying near bunch grass in their hunting position, apparently waiting for food. The grass clumps provide excellent cover providing they are old clumps that have previous years' dead growth lying down on the ground. These dried blades provide excellent insulation and buffer surface temperatures by as much as 22 C under the grass clumps, compared to bare ground nearby. We believe that these grass clumps may temporarily provide similar conditions to those in underground refugia. Winter data are needed to determine whether individual snakes use grass clumps as year-round homes or only for foraging or temporary thermal shelters. We have not found feces or shed skins under grass clumps as we have at other refugia.

Crotalus w. willardi tends to frequent canyon centers and creek bed perimeters, although they can be found in all areas of the study canyon. It is possible that populations may move around the canyon from creek center to ridgetop. They do seem to favor the south-facing aspect of either. More data are needed to show if this movement is real and, if so, if it is related to resources or environmental conditions. *C. w. willardi* do not exhibit regular surface activity when conditions are hot and dry, but will be found active during cool times, providing there is access to the sun for basking. We have found them moving in the rain, and have seen them basking in every month of the year, including basking on dry sunlit rocks less than three meters from snow. We have observed *C. w. willardi* in trees as high as 1.5 m, although rarely.

Crotalus w. willardi appear to be food generalists. Over the years we have observed the following in juvenile fecal samples: *Scolopendra heros* parts, unidentified orthopterans and *Sceloporus* (*S. scalaris* or *S. jarrovi*) scales (Table 9). Adult fecal samples contain mostly fur, but also *Sceloporus* scales. We have seen *C. willardi* consume all of the above food items in captivity.

We believe *C. w. willardi* live in pairs, with males possibly breeding multiple females in the late summer and early fall. We believe there is parental care and that babies stay with females for up to a month postpartum. Specific individual behavioral analyses are needed to confirm these anecdotal observations made over the past 20 plus years (Table 10).

Crotalus lepidus klauberi.--*C. lepidus klauberi* is a grassland and oak woodland, middle elevation, saxicolous species, preferring small rock talus piles and rock crevices for shelter.

They have been observed in burrows as well as grass clumps, but the majority of observations have been in rocks. Winter data are needed to determine whether rock crevices provide permanent homes or if they are used primarily for hunting. Similarly, where they occur below the surface in talus, it would be interesting to see if there are underground refugia for them. As noted in *C. willardi*, *C. lepidus* tend to use grass clumps more at lower elevations, but they still seem to occupy rocks when possible. *C. lepidus* have been seen by us at Canelo Hills with no visible rock formations for hundreds of meters. It is likely that *C. lepidus* use burrows or occupy underground rock piles at lower elevations, as they do slightly higher up (i.e., Lower Scotia Canyon). We believe the primary refugia are the places where we have found snakes with fecal matter and multiple shed skins in or under rocks or burrows under rock. We have found *C. lepidus* in trees up to 1.5 m, exhibiting undetermined behavior.

C. lepidus can be found in all areas of the study canyon, but they prefer south-facing rock piles. *Crotalus lepidus* appears to have regular hunting spots in or around the rock piles where they live. They are active all year but have low surface activity when it is hot and dry. As in *C. willardi*, winter-time basking is common and we have also observed them basking on sunlit dry rock < 1 m from snow pack. In our study area, all age classes of *C. lepidus* tend to feed on *Sceloporus jarrovi*. In captivity, juveniles have fed on pinkie mice, crickets, and lizards and most adults will accept mice.

We have regularly observed *C. lepidus* living in pairs with similar male fall movements as *Crotalus willardi*. We believe they also exhibit parental care for up to a month post parturition. One of us (HKM) has observed obvious guarding behavior by both parents toward neonates in captivity.

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